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Flow Response Tests of A Prototype Profiling Sonde Configuration

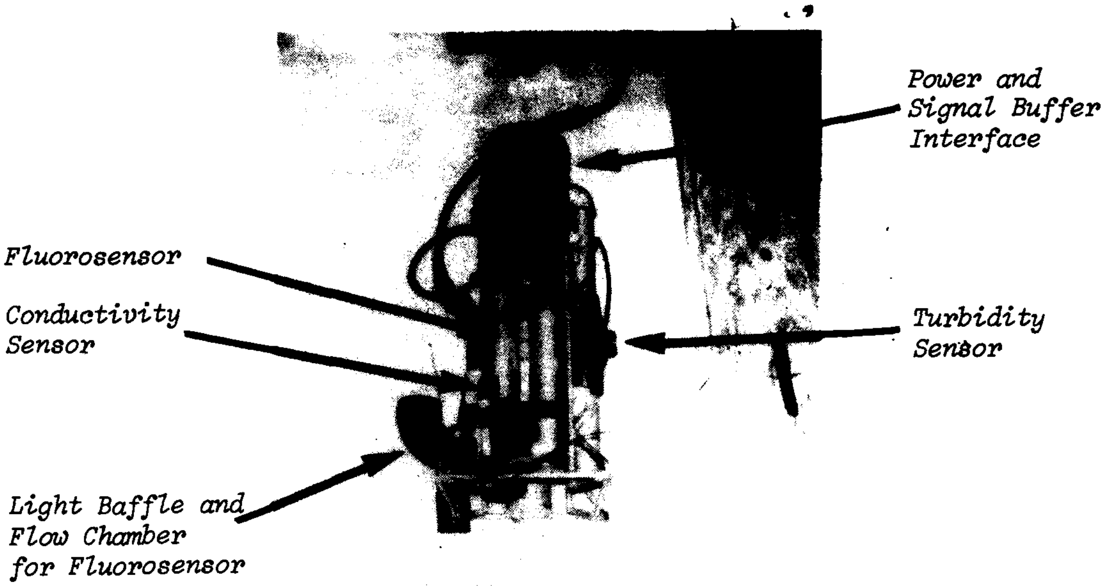
The response of sensors to various water quality and environmental parameters is usually well known on an individual basis, but, until recently, rarely determined on a system basis. This is largely the result of the difficulty associated with testing large systems by changing the environmental inputs when modifying the local environment of the sensor (changing the temperature to test temperature sensors, pressure to test pressure sensors, etc.) once it has been integrated into a system. The design of a lightweight profiling sonde for the National Water Research Institute, Pacific and Yukon region, necessitated the measurement of the "flushing" time[1] of the system sensors for conductivity, turbidity, and fluorescence. Since this type of response is dependent upon the flow field around the sonde, a system test was required.

Prototype Sonde

A prototype sonde package was built to simulate the expected form of the final design. This ensured that the "flushing" time measurements were relevant. Figure 1 is a photograph of the "mockup" sonde. The three

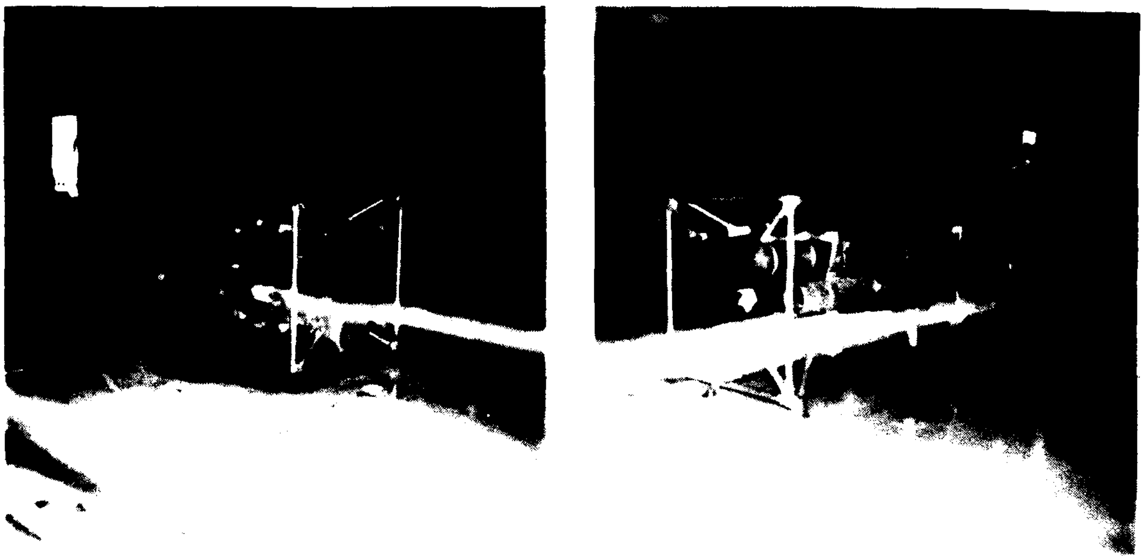
[1] (Note: The flushing time of a sensor used in profile measurements is defined as the time taken for the sensor to attain 99.3 percent of its steady state response after the passage through its flow chamber of a tagged volume of water.)

January 1980



Top View

FIGURE 1. Mockup of Prototype Sonde



Side View (a) *Side View (b)*

Figure 2. Photographs of Sonde Mockup in Flume

sensors are clustered with the inlets parallel and at the bottom of the sonde. A dummy tube represents the underwater data acquisition electronics package that will be used. The interface can at the top of the sonde is the only piece of equipment which was not sized to represent the final design. It was placed downstream of the inlets such that its presence would not affect the flow patterns at the inlets. The interface can provided power and signal buffering for the three sensors.

Tracer Solutions

Special tracer solutions were used in the "flushing" time experiment. The internal geometries of each of the sensors are taken into account by using tracer solutions specific to the sensor. The solutions used and the expected sensor responses are tabulated in Table 1.

TABLE 1
TRACER SOLUTIONS AND SENSOR RESPONSE

Sensor	Tracer Solution	Response
1. Conductivity	Distilled Water (clear)	output of sensor will decrease from ambient level to ~ 0 Vdc and then will return to the ambient level
2. Turbidity	MgOH (white, a 'pure' scatter of light)	output of sensor will increase from ambient level and then return
3. Fluorescence	chlorophyll "a" dissolved in acetone & isopropyl alcohol	output of sensor will increase from ambient level and then return
* high speed temp. probe*	cold water	output of sensor will increase from ambient level and then return

(*Note: The chlorophyll "a" solution resulted in a conflicting sensor output. A high speed temperature probe was inserted approximately in the center of the fluorosensor sample volume and cold water was subsequently used as a tracer solution.)

Experimental Setup and Procedure

The 2-metre flume of the Hydraulics Research Division, NWRI, was used throughout the system tests. Figure 2 (a) and (b) are photographs of the experimental setup in the flume. The sonde was aligned into the flow and positioned in the center of the flume. It was then levelled and bolted to the floor of the flume to prevent it from moving at the higher water velocities. The center lines of the turbidity, fluorescence, and conductivity sensor inlets were 25, 28, and 36 cm from the flume floor. The two adjacent flume sides were approximately 38 cm from the sonde (the width of the sonde is approximately 38 cm). The water depth of the flume was maintained at approximately 64 cm for all water velocities, except 75 cm/s where it was 45 - 55 cm.

Sensor "flushing" time response tests were performed at three water velocities: 10, 50 and 75 cm/s. Several injectors and different injection techniques were used. A 6.4 mm (1/4 in.) diameter stainless steel tube and a 12.7 mm (1/2 in.) diameter tygon tube were used to inject the conductivity and turbidity tracer solutions at various distances from the sensor inlets. At a flume speed of 10 cm/s the dispersion of each solution was large enough to cover the inlet areas with the injectors 5 to 15 cm (2 - 6 in.) from the inlets. At higher flume speeds, the injection occurred directly at the inlet. During the tests, it was found that the fluorosensor was not sufficiently responsive to the tracer solution consisting of chlorophyll "a" in acetone and isopropyl alcohol. A miniature, high speed thermistor temperature sensor was placed in the center of the fluorosensor sampling volume (within the flow chamber/light baffle) such that the flushing test could proceed with a temperature-specific tracer solution. A cylinder which was open at one end and had a removable plate seal at the other end was used to hold a

cold water solution. The open end of the cylinder was placed flush to the inlet of the fluorosensor flow chamber and the plate seal removed. A "cylinder" of cold water was thus forced through the chamber and detected by the temperature sensor. This test was only performed at the 50 cm/s flume speed.

The outputs of the three sensors were recorded on one of two chart recorders: an HP 7132A two channel recorder or a Gould two channel "Brush" recorder. The low range water velocity tests (10 cm/s) were recorded on the former, while the high range water velocity tests (50, 75 cm/s) were recorded on the latter.

Flushing Time Experimental Results

1. Conductivity Sensor

Figure 3(a) shows the output trace resulting from the injection of distilled water from a 6.4 mm (1/4 in.) diameter tube approximately 8 to 10 cm (3 to 4 inches) from the inlet of the conductivity sensor with a flow velocity of 12 cm/s. The distilled water mixes with the ambient water to produce an intermediate solution which is passed through the sensor.

Figure 3(b) and (c) are the output traces obtained by injecting distilled water from a 12.7 mm (1/2 in.) diameter tube flush to the inlet (at flow velocities of 50 and 75 cm/s). In this matter, an intermediate solution is not produced; the internal cavity of the conductivity sensor is saturated with distilled water until it is flushed away when the injector is suddenly removed. The step response of the conductivity sensor for this injection technique demonstrates significant overshoot on the falling and rising edges of the output signal. This is a sensor-related response and is likely a consequence of the electronic cell design and associated driver and signal-pickoff circuitry. This transient response has not been observed before and should be investigated further.

The flushing time measurements for the conductivity sensor are summarized in Table 2.

TABLE 2

FTR LIGHTWEIGHT PROFILER MOCKUP
FLUSHING RATE TESTS

Avg. Water Vel. (cm/s)	Time Const. 63.2% (sec)	Flush Time 99.3% (sec)	Comments
1. Conductivity Sensor			
12	2.9	36.9	avg. of 3 tests, small bore injector 2-3 inches from inlet
52	0.39	3.7	avg. of 3 tests, large bore injector flush to inlet
75	0.23	0.62	1 test, large bore injector flush to inlet
2. Turbidity Sensor			
12	9.6	64.2	avg. of 2 tests, small bore injector 4-6 in. from inlet
52	0.49	4	avg. of 2 tests, large bore injector 1-2 in. from inlet
75	0.51	1.62	avg. of 2 tests, large bore injector 1-2 in. from inlet
3. Fluorosensor			
52	0.45	2.3	1 test, high speed thermistor probe in sample vol. - injected cold water

2. Turbidity Sensor

Figure 4(a), (b), and (c) are the step responses recorded for the turbidity sensor. Its response time is typically slower than the conductivity sensor, but represents approximately the maximum speed of response that it can attain. (It is well known that this particular sensor has a response time that varies with the signal level. It responds faster at high turbidity levels than at low turbidity levels.) The flushing time measurements obtained from Figure 4(a), (b), and (c) are shown in Table 2.

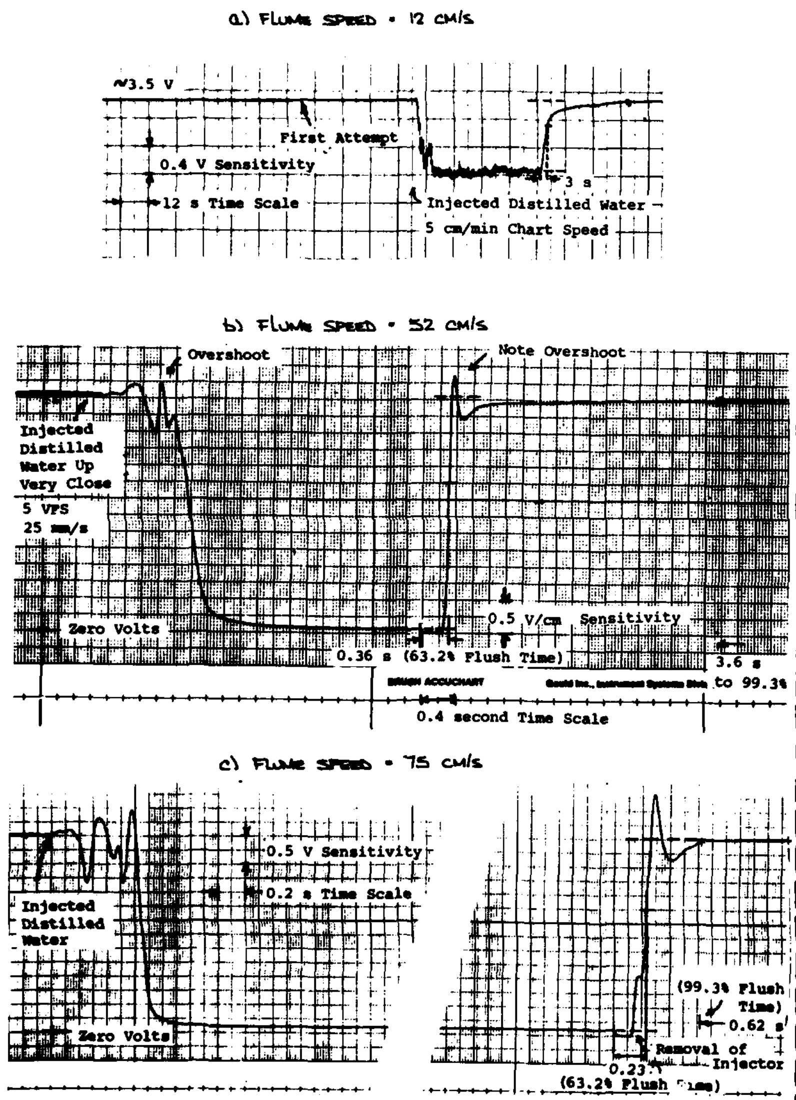


FIGURE 3

CONDUCTIVITY SENSOR RESPONSES

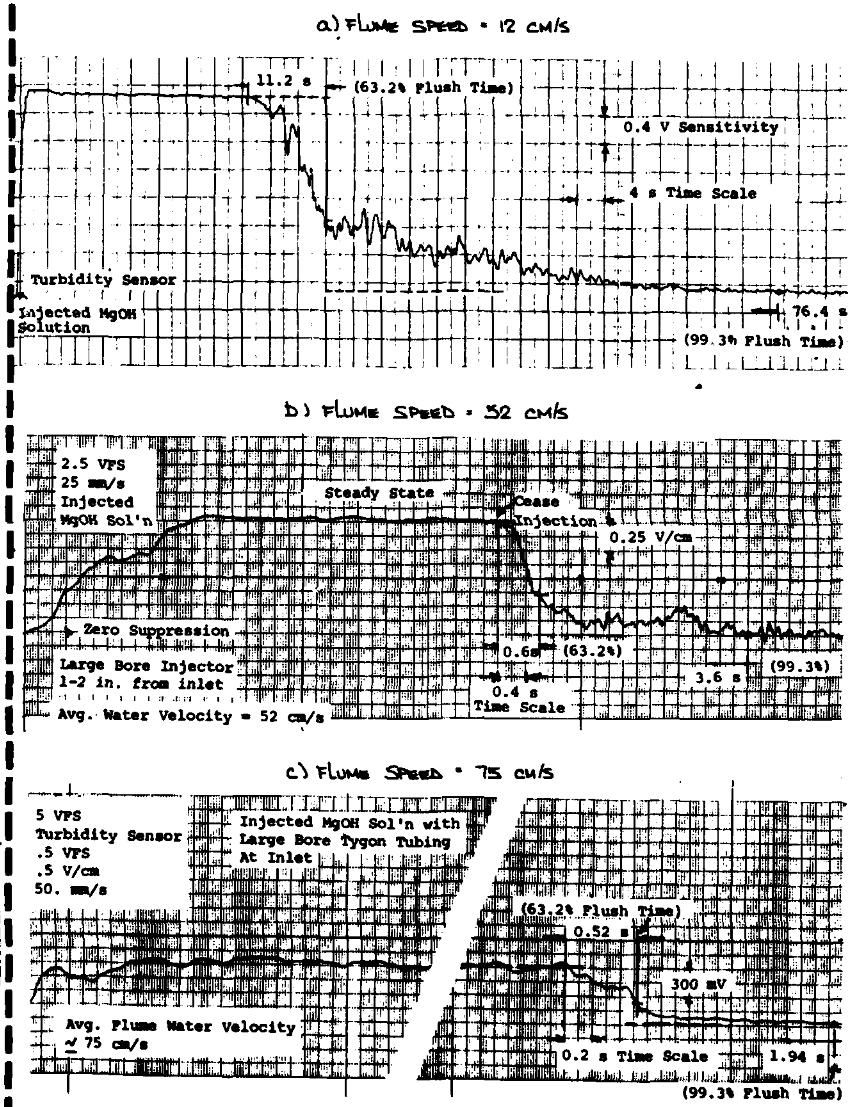
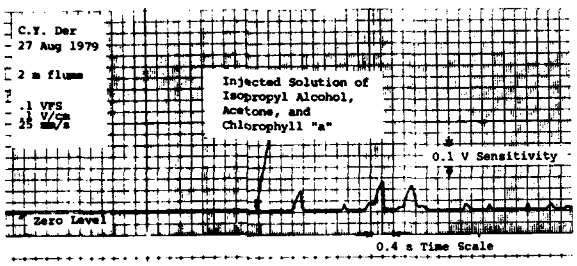


FIGURE 4

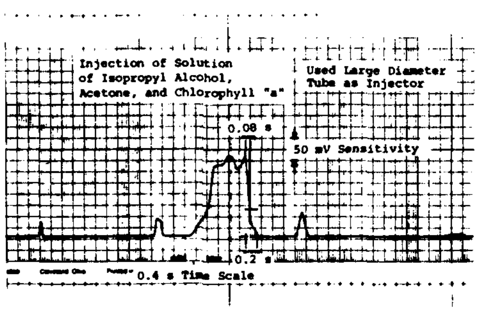
TURBIDITY SENSOR RESPONSES

3. Fluorosensor

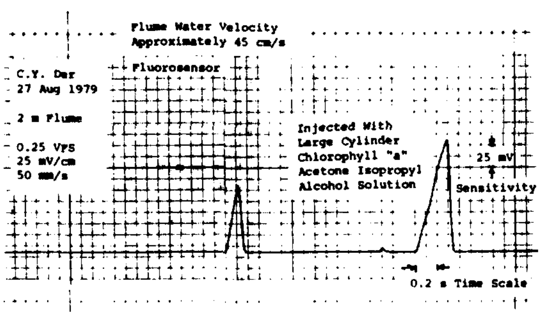
Injection of the chlorophyll "a", acetone, isopropyl alcohol solution at 10, 50 and 75 cm/s resulted in the output traces shown in Figure 5(a), (b), and (c). The florosensor appears to be detecting discrete "packets" of solution. This results from the tracer solution being immiscible in water which causes globules of solution to form and their passage through the flow chamber is detected discretely. A tracer solution based on methanol instead of acetone would be better suited for this test. As this new tracer solution was not available, a different method of determining the "flushing" time of the fluorosensor flow chamber/light baffle was required. As described earlier in a preceding section, a high speed thermistor probe was inserted in the center of the flow chamber and a cold water solution was used as a tracer. The thermistor response to the injection of cold water is shown in Figure 6. The measured "flushing" time is included in Table 2.



a) Flume Speed - 12 cm/s



b) Flume Speed - 52 cm/s



c) Flume Speed - 75 cm/s

FIGURE 5
FLUOROSENSOR RESPONSES

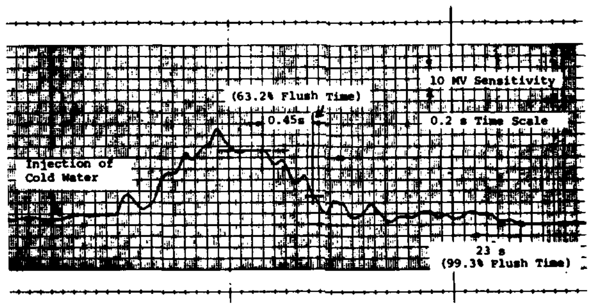


FIGURE 6
HIGH SPEED THERMISTOR RESPONSE IN FLUOROSENSOR LIGHT BAFFLE / FLOW CHAMBER

Conclusions

As evident in Table 2, the time constant and "flushing" time of the conductivity, turbidity and fluorescence sensors in the prototype sonde configuration are non-linear functions of the flow velocity and are hydrodynamically limited. The spatial uncertainty of measurements taken with these sensors in this flow configuration can be estimated from the "distance" constants associated with each sensor (distance constant = flow rate x speed of response).

Table 3 is generated from Table 2 and shows that the optimum profiling speed for the PYR lightweight

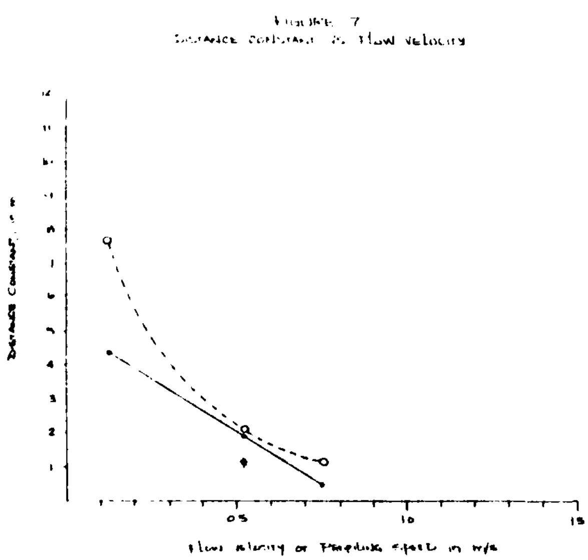
TABLE 3

SENSOR DISTANCE CONSTANTS

Distance Constant (m)	99.3% & 63.2% Sensor Response for Various Profiling Speeds		
	.12 m/s	.52 m/s	.75 m/s
Conductivity	4.4 (0.35)	1.9 (0.20)	0.5 (0.17)
Turbidity	7.7 (1.15)	2.1 (0.25)	1.2 (0.38)
Fluorescence	-	1.2 (0.23)	-

Numbers without brackets are the 99.3% response measurements.
Numbers with brackets are the 63.2% response measurements.

profiler (which produces the smallest distance constants) is about .75 m/s. This is a surprising result as, intuitively, one would expect that the most accurate profiles are obtained at the slower profiling speeds. Figure 7 is a graph of the distance constant calculated from the flushing time versus the flow velocity for the three sensors. Beyond a flow velocity of approximately 1 m/s, the distance constants for the sensors appear to become independent of the flow velocity.



In summary, for a profiling speed between .75 and 1 m/s, the distance constant of the conductivity, turbidity, and fluorescence sensors is approximately 0.5 to 1 m.

Acknowledgments

The author gratefully acknowledges the co-operation and assistance provided by Dr. Y. L. Lau and the technical staff of the Hydraulics Research Division, NWRI. Other persons who contributed to the construction of the prototype sonde and provided valuable input to the test program include H. Savile, F. Roy and J. S. Ford of the Engineering Services Section.

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A Connectorless Shielded Electrical Cable Pressure Seal

Shielded cable connectors presently used for oceanographic equipment are bulky and unreliable. Here we present the design for a feedthrough that is relatively small, simple to construct, and has been tested to 6,000 psi. Figure 1 shows how we bond the electrical cable to the pressure seal. P.V.C. materials were selected so that they could be bonded using P.V.C. primer and glue. The wire is bonded to the pressure seal at the top using an abundant amount of glue and letting air dry for at least 12 hours. The pressure seal uses two "O" rings, Parker No. 2-004 on the bottom and Parker No. 2-010 on the side. Since the wire insulation will be exposed to sea water, it should be carefully inspected for pinholes (we have not found this to be a problem) and protected from abrasion in use.

The above design enables one to feedthrough a two-conductor shielded cable in the same space normally required for a single pin.

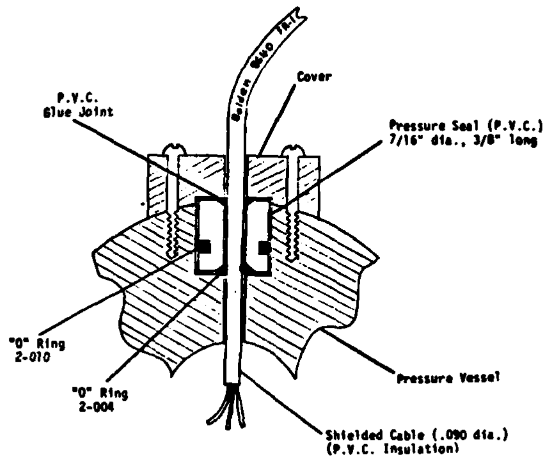

Figure 1. A shielded cable pressure seal mounted in a pressure vessel.

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